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Former Plainwell Impoundment and Plainwell No. 2 Dam Area 2012 Bank Conditions Monitoring Report

Georgia-Pacific LLC

December 2012

ARCADIS

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Our Ref.:
B064530.0003.00907

Date:
December 2012

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Table of Contents

Tables

Figures

Attachments

1. Introduction

This *Former Plainwell Impoundment and Plainwell No. 2 Dam Area Final 2012 Bank Conditions Monitoring Report* (Monitoring Report) presents the results of bank monitoring activities performed in 2012 in the former Plainwell Impoundment and the Plainwell No. 2 Dam Area, both located on the Kalamazoo River in Plainwell, Michigan (Figures 1 and 2). Georgia-Pacific LLC (Georgia-Pacific) and ARCADIS have been conducting an annual monitoring program in these areas to observe and document various characteristics of the floodplains and river banks since completion of the Time-Critical Removal Action (TCRA) implemented in each area.

Per the Administrative Settlement Agreement and Order on Consent for Removal Action (AOC) for the former Plainwell Impoundment, Docket No. V-W-07-C-863, dated February 21, 2007 (U.S. Environmental Protection Agency [USEPA] 2007) and the AOC for the Plainwell No. 2 Dam Area, Docket No. V-W-09-C-925, dated June 8, 2009 (USEPA 2009), bank monitoring is required annually for a period of three years. The three-year monitoring period, which started following the issuance of a *Notice of Completion of Work* by USEPA, is different in each area. In the former Plainwell Impoundment, the *Notice of Completion of Work* was issued March 30, 2010 (USEPA 2010), so the monitoring period will end on March 30, 2013. The *Notice of Completion of Work* for the Plainwell No. 2 Dam Area TCRA was issued March 1, 2011 (USEPA 2011), so the monitoring period will end on March 1, 2014.

Following completion of the three-year bank monitoring requirements for the former Plainwell Impoundment, the Michigan Department of Natural Resources (MDNR) has agreed to perform post-removal site control activities, including bank monitoring. With regard to the reporting requirements, MDNR will submit the required annual report until such time that USEPA and MDNR agree that the banks addressed under the removal action as required by the AOCs are sufficiently stabilized, and the vegetation sufficiently restored, such that no further annual reporting is necessary. Beyond that point, MDNR will submit a report to USEPA only in those years when a significant change has occurred in the condition of the vegetation or banks, and/or when MDNR has taken a significant action to address a change in the condition of the vegetation or banks.

There is no defined transition plan for the Plainwell No. 2 Dam Area following completion of the bank monitoring period on March 1, 2014.

This Monitoring Report describes the relevant performance standards established in the TCRA design reports (ARCADIS BBL 2007 and ARCADIS 2009a) and the methodology used for the

field observations. The monitoring program includes two data collection events. The following observations are performed each spring:

- visual inspections
- a topographic survey (used to develop bank profiles)
- an assessment of the Bank Erosion Hazard Index (BEHI) ratings for the targeted banks (to compare to bank conditions observed in prior years)
- woody vegetation survival monitoring
- an evaluation of invasive weed presence

An assessment of the status of herbaceous ground cover is performed each fall.

The spring 2012 monitoring results were previously submitted to USEPA and the Trustees in the *Former Plainwell Impoundment and Plainwell No. 2 Dam Area Spring 2012 Bank Conditions Monitoring Report* (Spring 2012 Monitoring Report; ARCADIS 2012a). Those prior observations and assessments were used to inform the regulating agencies of the status of the restored banks, and propose areas for maintenance activities. The results were discussed with USEPA and the Natural Resource Trustees[1] – the Michigan Department of Environmental Quality (MDEQ), MDNR, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Fish and Wildlife Service (USFWS) – during a collaborative onsite inspection/meeting referred to in this report as the Trustee Site Walk, which was held on August 30, 2012. Follow-up site walks were held on September 19, October 25, and December 3, 2012 and follow-up calls were held on September 17, 2012 and October 4, 2012 to discuss bank areas potentially requiring maintenance in 2012. Comments on the Spring 2012 Monitoring Report and observations made during the site walks were provided by the Trustees on October 15 (USEPA 2012a), October 25 (MDEQ 2012a), October 26 (MDEQ 2012b), and December 3, 2012 (USEPA 2012b). This report incorporates the outcomes of the onsite meetings and discussions, and reflects the responses developed to address the written comments. Responses to the written comments from USEPA and MDEQ (USEPA 2012a and MDEQ 2012b) are also being submitted concurrent with this report. A response to the site inspection reports (USEPA 2012b and MDEQ 2012a) is included in this report.

[1] The Trustees, with the exception of the MDNR, were not signatories to the AOC. The Trustees were consulted during this process for their input and guidance. Final decision-making authority on any issue rested with the signatories to the AOC. Although not considered a Trustee, the Michigan Department of Attorney General is also a signatory to the AOC.

The results of the spring monitoring activities are included in this annual report, along with the following additional information:

- The results of the summer 2012 vegetation quadrant monitoring
- Photographs documenting the vegetation development during the 2012 growing season
- Results of meetings held in 2012 with USEPA and Trustees
- Adaptive management activities implemented in 2012
- Adaptive management activities to be implemented in 2013

1.1 General

The activities described in this Monitoring Report were performed in accordance with the USEPA-approved *Former Plainwell Impoundment Time-Critical Removal Action Design Report* (Former Plainwell Impoundment Design Report; ARCADIS BBL 2007), the *Plainwell No. 2 Dam Area Time-Critical Removal Action Design Report* (Plainwell No. 2 Dam Area Design Report; ARCADIS 2009a), and post-construction monitoring discussions with representatives of USEPA and the Trustees.

1.2 Project Area Description

1.2.1 Former Plainwell Impoundment

The former Plainwell Impoundment is located in Gun Plain and Otsego Townships, on the Kalamazoo River downstream of Plainwell, Michigan. It is roughly bounded on the upstream (or southeastern) end by the Main Street Bridge in Plainwell, and on the downstream (or northwestern) end by the former Plainwell Dam location (Figure 1).

As part of the TCRA, river banks targeted for excavation were rebuilt after construction using a combination of sand backfill and either deep-rooted vegetation or river run rock to control erosion, with topsoil installed as necessary to support revegetation. Vegetation and riparian habitat was established by seeding and planting in three different hydrologic zones. The basis for the design of these zones is described in Section 2.7 of the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007). Native plant species reviewed and approved by MDNR prior to use were installed in habitat restoration areas. Following installation of woody vegetation, saplings were tied to two stakes for support and all species were surrounded with a

ring of woody mulch. Bank revegetation activities were completed in Removal Areas 1 through 6B in October 2008 and vegetation of the remaining removal areas (Removal Areas 7 through 13) was completed in June 2009.

Temporary access roads were removed and the underlying ground was restored to pre-construction conditions by removing the road material and fabric, disking the ground surface to un-compact the topsoil, and seeding with the upland seed mix to restore vegetation.

1.2.2 Plainwell No. 2 Dam Area

The Plainwell No. 2 Dam Area is located on the Kalamazoo River approximately 3.5 miles upstream of the former Plainwell Dam in the city of Plainwell and Gun Plain Township, Allegan County (Figure 2).

As TCRA removal operations were completed within a removal area, the river banks were reconstructed or graded to the design slope (ARCADIS 2009a) and revegetated. Banks were rebuilt using a combination of sand backfill and river run rock to control potential erosion. Coir log and temporary erosion control fabric were installed as necessary to provide protection during the establishment of vegetation, and topsoil was installed as necessary to provide a suitable growing medium. Vegetation and riparian habitat were established using the same approach described above for the Former Plainwell Impoundment and as detailed in Section 3.5 of the Plainwell No. 2 Dam Area Design Report (ARCADIS 2009a).

Grubbed areas that were vegetated prior to construction (fields, vegetated areas, etc.) were restored. Where necessary, a 6-inch layer of topsoil was placed to restore pre-excavation grades, followed by placement of grass seed and straw or erosion control blanket. New trees and shrubs were installed in accordance with the appropriate vegetation zone in which the disturbed area was located.

1.2.3 Storm Events Affecting Kalamazoo River Flows

Kalamazoo River flows at the United States Geological Survey (USGS) Comstock gage (USGS 04106000 Kalamazoo River at Comstock, MI) exceeding the 2-year storm event (2,940 cubic feet per second [cfs]; MDEQ 2007) have occurred at the following times since the initial construction-related disturbances to the banks as part of remedial activities:

- September 2008 (9-day duration with 5,660 cfs maximum flow, approximately a 25-year storm flow based on communication with MDEQ [MDEQ, pers. comm. 2009])
- December/January 2008-2009 (3-day duration with a 3,370 cfs maximum flow)

- February 2009 (4-day duration with a 3,320 cfs maximum flow)
- March 2009 (7-day duration with a 4,580 cfs maximum flow)
- March 2010 (2-day duration with a 3,000 cfs maximum flow)
- June 2010 (1-day duration with a 2,950 cfs maximum flow)
- July 2010 (4-day duration with a 3,210 cfs maximum flow)
- May/June 2011 (6-day duration with a 4,150 cfs maximum flow)

The first four events occurred after the initial construction disturbance of the banks; the last four of these events occurred after completion of restoration activities in the former Plainwell Impoundment. The September 2008 event occurred following restoration and initial planting of several removal areas in the upstream section of the former Plainwell Impoundment.

The September 2008 storm was estimated to be a 25-year return frequency event – this kind of significant event has particular bearing on the understanding of bank stability. As of September 2008, excavation had been completed in all removal areas except Removal Areas 11A, 13A, and 13B; Cofferdam Area 2, and Mid-Channel Area A. These areas had been backfilled and planted but were in various stages of developing vegetation and were relatively more susceptible to erosion before soil consolidation and growth of more vegetation occurred following completion of all TCRA restoration activities. The September 2008 storm had the potential to be a significant channel-forming event. In non-entrenched streams, the bankfull storm event is often referred to as the channel forming flow, as it represents maximum bank stresses before flows spill into the floodplain. As such, banks that have exhibited stability following exposure to several bankfull events are likely to remain that way under similar conditions in the future, as vegetation and rooting becomes more established over time. Per Section 5.6 of the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007), "*Banks and riparian habitats observed to be stable after a 2-year storm will be concluded to be stable.*" Multiple flows exceeding the 2-year event flow have occurred since completion of the TCRA in the former Plainwell Impoundment.

1.3 Bank Conditions Monitoring Program

In accordance with the AOCs (USEPA 2007, 2009) and as detailed in the TCRA Design Reports (ARCADIS BBL 2007 and ARCADIS 2009a), monitoring of the restored banks is required to be performed annually for three years following USEPA's *Notice of Completion of Work* (issued March 30, 2010 for the former Plainwell Impoundment and March 1, 2011 for the Plainwell No. 2 Dam Area). This Monitoring Report discusses data collected during 2012

monitoring events to satisfy the annual requirements. The 2012 monitoring program was carried out consistent with prior monitoring events, and consisted of the following activities:

- Visual inspections and evaluations of bank conditions
- Topographic survey of bank profiles at 37 permanently benchmarked locations (23 in the former Plainwell Impoundment and 14 in the Plainwell No. 2 Dam Area)
- Use of the BEHI developed by Rosgen (1996) as a monitoring tool to describe characteristics that contribute to bank stability at 26 previously-rated locations and two new locations in the former Plainwell Impoundment; and at nine previously-rated locations and two new locations in the Plainwell No. 2 Area
- Qualitative evaluation of invasive weed presence
- Woody plant stem density assessment
- Quantification of herbaceous ground cover
- Photo-documentation of vegetation development on restored bank areas

1.4 Document Organization

This Monitoring Report is organized into eight sections, consisting of this introductory section (Section 1) and the following seven sections:

- Section 2 - Monitoring Objectives, presents the objectives that were established to evaluate the restored areas.
- Section 3 – Bank Monitoring Methodologies. Summarizes the methods used to perform the annual monitoring activities.
- Section 4 – Former Plainwell Impoundment Bank Monitoring Results. Presents the results of the 2012 monitoring efforts for the former Plainwell Impoundment and compares the results to the established performance standards.
- Section 5 – Plainwell No. 2 Dam Area Bank Monitoring Results. Presents the results of the 2012 monitoring efforts for the Plainwell No. 2 Dam Area and compares the results to the established performance standards.
- Section 6 – Maintenance Activities. Describes adaptive management or maintenance activities that are being proposed for 2012 to assist in achieving the performance standards.

- Section 7 – Future Monitoring and Reporting Activities. Summarizes future monitoring and reporting activities.
- Section 8 – References.

2. Monitoring Objectives

Monitoring objectives and, for some aspects, performance standards were developed during the preparation of the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007) and the Plainwell No. 2 Dam Area Design Report (ARCADIS 2009a). Performance standards are quantitative measures that are used along with qualitative information to evaluate vegetation survival and development. The purpose of the monitoring program, the objectives, and performance standards are presented in the following sections.

2.1 Monitoring Purpose and Objectives

The purpose of the bank monitoring and visual inspections is to identify conditions of potential concern, such as signs of detrimental erosion or bank failure that may impact the functionality of restored banks or jeopardize top-of-bank land uses. Those conditions of potential concern are then discussed with the Trustees to determine where an adaptive management approach may be required. The adaptive management approach is described in Section 6.4.

According to Section 5.6 of the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007) and Section 5.7 of the Plainwell No. 2 Dam Area Design Report (ARCADIS 2009a), restored bank conditions are to be monitored annually for signs of erosion and sloughing for a period of three years following the completion of construction. Monitoring activities include conducting a visual inspection of bank conditions, developing written inspection logs, and photographing any conditions of note, including:

- Obvious signs of gullying or rill erosion
- Bank undercutting
- Signs of sloughing (i.e., cracking or bulging visible at the surface)
- Loss of armoring materials (i.e., loss of stones, erosion control matting, and/or vegetation)
- Any obvious signs of lateral bank movement (i.e., due to erosion or deposition)

Through subsequent discussions with the Trustees, it was agreed that annual monitoring reports would include results from inspecting and recording conditions of the banks, collecting bank profile survey data for comparison to prior surveys, and using the visual evaluations and BEHI rating approach to evaluate temporal changes in bank condition. The methodology for the visual evaluations and BEHI ratings are presented in Section 3.3.

2.2 Survivability and Natural Recruitment of Woody Vegetation

The vegetation-based performance standard is related to the survival and natural recruitment of woody vegetation consisting of native trees and shrubs. Trees and shrubs of various sizes were planted in habitats that supported woody vegetation prior to disturbance during the TCRAs. Planting density reflected densities observed during pre-disturbance characterization activities and consisted of 125 shrubs and 50 trees per acre in Zone 2 and 225 shrubs and 75 trees per acre in Zone 3 of the former Plainwell Impoundment, and 225 shrubs and 75 trees per acre in Forested Wetlands and 225 shrubs and 75 trees per acre in Forested Uplands of the Plainwell No.2 Dam Area to create the desired communities.

The performance standard for woody vegetation is the presence of 85% of the total number of trees and shrubs planted by the third growing season. The methodology for calculating the quantity of trees and shrubs present in restored areas is discussed in Section 3.4 of this Monitoring Report. Naturally recruited native tree and shrub species that become established in the project area are counted for comparison to the original stem density as they are positive indicators that appropriate environmental conditions have been established for the desired plant community. If 85% of the number of originally planted trees and shrubs do not become established by the third growing season, adaptive management maintenance activities are to be implemented to improve the vegetative community, as discussed in Section 6.4 of this Monitoring Report.

2.3 Herbaceous Ground Cover

The herbaceous ground cover performance standard requires that at least 85% of the ground surface be covered by vegetation by the third growing season. Restored banks in the project areas were seeded with seed mixes appropriate for the hydrologic conditions of the restoration areas. A variety of tree and shrub species were planted to restore woody vegetation in forested and shrub habitats. The percent cover evaluation methodology utilizes percent cover data collected from randomly-located standardized sampling quadrants, as discussed in Section 3 of this Monitoring Report. Meeting or exceeding the 85% ground cover performance standard is evidence that the vegetation will be self-sustaining. If the 85% ground cover performance standard is not met before the end of the third monitoring year and it is determined that the vegetation is not developing adequately to meet this performance standard by the third growing season, maintenance activities may be implemented, as discussed in Section 6 of this Monitoring Report.

2.4 Bank Status in Restored Areas

Although not specifically stated in either of the Design Reports, prior to the preparation of the first monitoring report in 2009, Georgia-Pacific and the Trustees agreed that vegetation monitoring results, BEHI bank ratings, visual observations, and surveyed bank cross-section data would be used to assess the bank characteristics related to stability over time. The BEHI bank ratings are a tool used in conjunction with the other information considered, but are not relied upon to determine bank stability alone.

2.5 Adaptive Management

In an adaptive management approach, observations of river tendencies are interpreted to evaluate their significance to the quality of the river and its riparian habitat. Adaptive management is being used in the evaluation of bank and floodplain conditions as the long-term water elevations become established. Specific attention is being paid to the final water/bank interface where the majority of observed erosion is occurring. Adaptive management remedies will be identified (as necessary) to address erosion and improve the overall habitat quality of the river shoreline. Adaptive management activities have included the installation of rock armor and coir logs to protect the banks and increase the vegetative density of the shoreline. Other measures, such as reseeding or installing plant plugs where seeding was ineffective, or increasing the amount of armor protection will be evaluated on a case-by-case basis and discussed with the appropriate oversight agencies prior to installation.

The adaptive management approach is being applied as appropriate when conditions of note are observed to evaluate what specific response actions will be taken, if any, and the scheduling of such response actions. The results (i.e., final conditions) of any response actions will be documented in writing and with photos immediately following implementation. The performance of any such response actions will be documented after a period of one year following implementation of the response action or during the next scheduled monitoring event, whichever occurs sooner.

3. Bank Monitoring Methodology

The following sections describe the specific methodologies employed by field crews during the 2012 monitoring events.

3.1 Visual Inspection

During bank inspection, restored banks were inspected for signs of erosion that would jeopardize the integrity of the banks or their functionality in the river system. The limits of a "bank" extend from the toe-of-slope to the first visually observable break in slope. Signs of significant erosion include toe erosion causing undercutting, lateral erosion above the rock protection, exposed geotextile fabric, or vertical erosion down the face of the bank from overland flow entering the river. The status of restored banks was evaluated by visual observation and comparison to design drawings, considering location in the river, physical dimensions, and consistency with adjacent, undisturbed banks. The Former Plainwell Impoundment Design Report (ARCADIS BBL 2007) and the Plainwell No. 2 Dam Area Design Report (ARCADIS 2009a) specify that at least one bank monitoring event be performed after the bank has been exposed to a two-year (or greater) storm event. A two-year (or greater) flood represents a high-stress exposure for restored banks and presents a relatively high potential for bank failure. Since initial construction disturbance of the banks, banks in the former Plainwell Impoundment experienced eight storms greater than the two-year event, the northern banks of the Plainwell No. 2 Dam Area experienced four storms greater than the two-year event, and the southern banks of the Plainwell No. 2 Dam Area experienced two storms greater than the two-year event (see the list of storm events in Section 1.2.3).

The spring 2012 bank inspection, performed from May 2-4, 2012 in the former Plainwell Impoundment and from April 30-May 1, 2012 in the Plainwell No. 2 Dam Area, consisted of visually inspecting bank conditions, photographing the banks, and recording conditions of note, as described in Section 2.1.

3.2 Topographic Survey

In addition to the visual inspection of the banks, bank profiles were surveyed at established transect locations to compare bank geometry to post-construction conditions and surveys from previous years. These same locations are resurveyed in the spring (April/May/June) of each monitoring year. Data are collected to evaluate differences in characteristic bank morphology as an indicator of bank stability. There is no quantifiable performance standard included in the monitoring program, so the comparison of bank geometry over time is used in combination with the visual inspection and the BEHI results to evaluate bank characteristics that are related to

stability. ARCADIS collected as-built and post-construction survey transect data through 2010. Prein and Newhof of Grand Rapids, Michigan performed the 2011 and 2012 topographic surveys.

3.3 BEHI Rating

The bank monitoring program was developed to incorporate components of the BEHI methodology developed by Rosgen (1996). The BEHI integrates information regarding the relationship of the top-of-bank height to the bankfull water elevation, the vertical extent of root penetration in the bank, the root density, the bank angle, and the percentage of bank surface protected by vegetation or armor to identify a qualitative erosion hazard rating of “very low,” “low,” “moderate,” “high,” “very high,” or “extreme” (Table 1). BEHI data are collected annually at locations selected in the field from lengths of bank with similar characteristics (e.g., slope, geometry, bank armoring). Each similar length of bank is then assigned a BEHI rating from the collected data.

A typical BEHI evaluation utilizes data to represent characteristics from the toe of slope to the top of bank. Although the BEHI was not used in the design of the TCRA projects, for the purposes of the monitoring efforts, bank descriptors have focused on the restored portion of the bank, which typically extended from the toe-of-bank to below the bankfull elevation. Using these data in this way allowed a refined assessment that could discern differences in bank conditions from year to year, and eliminated factors that were constant and not relevant to discerning differences, such as the upper portion of a densely vegetated bank.

Comparisons of the lengths, locations, and ratings of the restored banks over time provides a method to track improving or degrading bank conditions, and the predominant ratings throughout the river. The comparison of the BEHI ratings throughout the three-year monitoring period provides a general indication of changes in bank conditions and may assist in identifying areas where maintenance may potentially be needed. BEHI ratings of “low” and “very low” can be considered to have a low potential for erosion; BEHI ratings of “high” or “extreme” have a higher potential for erosion. A “moderate” BEHI rating falls between these conditions.

3.4 Vegetation Monitoring

Vegetation establishment and development contributes to bank stability by providing: 1) ground cover that reduces the potential for erosion by sheetflow, and 2) physical support for banks from woody root systems. Areas of restored vegetation were observed, and the percent cover and stem densities compared against the performance standards described in Section 2.2 to evaluate the development of the desired plant communities. Monitoring of woody vegetation

(counting trees and shrubs) is typically performed in the spring to allow easier observation of targeted plants when herbaceous vegetation is still low, and herbaceous vegetation is observed in the late summer.

3.4.1 Woody Vegetation

The tree count was performed in April and May 2012 by inspecting the restored portions of the project areas that were planted with trees and shrubs and counting all live trees and shrubs in the revegetation areas. Naturally recruited trees and shrubs were included in the stem count (along with plants installed as part of the TCRAs) if they were taller than 18 inches. The number of observed woody plants was compared to the number of trees and shrubs originally planted to calculate the percentage of the original planted stem density that currently exists in the planting area. That value is compared to the 85% stem density performance standard to determine if the standard has been met or if supplemental plantings are required.

3.4.2 Herbaceous Vegetation

The summer annual monitoring inspection consisted of the collection of herbaceous ground cover data during the peak growing season to assess the health and development of herbaceous vegetation restored by seeding. Visual assessment of the total percent ground cover and the relative percent ground cover of all identifiable species was collected from 1-meter-square plots located randomly throughout restored habitats at a frequency of 10 plots per acre. Herbaceous vegetation data collection occurred between August 13 and 16, 2012. The mean percent ground cover of all of the data plots was compared against the 85% ground cover performance standard that must be met by the third growing season.

The summer annual inspection also noted any observed exotic/invasive species. Implementation of an exotic/invasive species control program is one part of a successful revegetation program. Species to be monitored in the project areas include exotic/invasive species and other aggressive species with a tendency to develop into mono-cultures, such as broad-leaved cattail (*Typha latifolia*), common reed (*Phragmites australis*), multiflora rose (*Rosa multiflora*), purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), autumn olive (*Elaeagnus umbellata*), garlic mustard (*Alliaria petiolata*), and yellow iris (*Iris pseudacorus*). Control of exotic/invasive species is determined on a case by case basis. See Section 6.5 for additional information.

4. Former Plainwell Impoundment Bank Monitoring Results

Instrument surveys of the restored banks and woody vegetation surveys were performed in March 2012, physical bank inspections occurred in April 2012, and herbaceous vegetation monitoring occurred in August 2012.

The following sections summarize the results of the surveyed transect comparisons, the BEHI ratings, the woody vegetation monitoring, and the herbaceous vegetation monitoring in the former Plainwell Impoundment. Supporting information is provided as follows:

- The cross-sections of the restored banks at the 23 permanent transect locations identified on Figure 3 are presented on Figures 4 through 11.
- The transect survey data since 2009 are summarized in Table 2, the BEHI data are summarized in Table 3, and the erosion hazard ratings for the restored banks are presented on Figure 12.
- Photographs of the banks exhibiting various BEHI ratings are presented in Attachment 1.
- The results of the tree and shrub woody vegetation stem counts are summarized in Table 4, and the detailed data are presented in Attachment 2.
- Herbaceous vegetation data are summarized in Table 5 and the detailed vegetation data are presented in Attachment 3.
- Photographs of the vegetation status on restored banks are presented in Attachment 4.

4.1 Comparison of Surveyed Banks

Twenty-two permanent bank cross-section locations were benchmarked in 2009 to allow annual replication of the cross-sections to evaluate bank conditions. A twelfth location was added in 2011 to evaluate the northern bank upstream of the US 131 Bridge. The locations of the 23 transects are shown on Figure 3. Detailed bank survey data collected immediately following the physical restoration of the banks in 2009, and in spring 2010, 2011, and 2012 are presented on Figures 4 through 11. Year-to-year comparisons of observations made from the transect data are included in Table 2.

Survey transects were initially reviewed with the intention of identifying areas for additional inspection and discussion as part of the August 30, 2012 site walk (see Table 2). The lateral

and vertical change in bank elevation from one monitoring event to the next is presented. Although the change is quantified, the purpose of the summary in Table 2 is to present a qualitative comparison of transect information. For this purpose, each value is rounded to the nearest half foot. Changes of less than 6 inches are within the range of error associated with survey data collection and evaluation. Any observed change of less than half a foot is considered to be insignificant. The absolute value of material loss or deposition is not as important as the geometry of the bank profile from year to year. The profiles of the banks are classified as:

- Consistent with the previous year.
- Material loss or deposition was observed, but not to the extent that the bank may be at risk of immediate failure or the top-of-bank land use jeopardized.
- Material loss or deposition was observed, to the extent that warranted additional inspection and discussion at the August 30, 2012 site walk.

In summary, 7 of the 20 transects (35%) showed a bank profile consistent with the bank profile observed in 2011; 8 of the 20 transects (40%) showed evidence of material deposition or loss that altered the bank profile since 2011, but not to the extent that warranted additional inspection; and 5 of the 20 transects (25%) – T-3N, T-4S, T-10N, T-11N, and T-12N – were identified for additional inspection during the 2012 Trustee Site Walk.

Of the 13 transects that showed evidence of material deposition or loss, material deposition above the water line was observed in 5 of the 13 transects (38%), material deposition below the water line was observed in 2 of the 15 transects (8%), material loss above the water line was observed in 5 of the 13 transects (38%), and material loss below the water line was observed in 11 of the 13 transects (85%).

4.2 Bank Erosion Hazard Index Ratings

BEHI ratings were calculated for each bank area addressed as part of the TCRA based on observed field characteristics in 2012, and the results were compared to previous years. In response to MDEQ comments on the 2011 monitoring report, BEHI values were recalculated from the 2011 data using bank heights extrapolated from the closest surveyed bank transect. During previous BEHI evaluations, percentages of root depth were determined based on visual estimates – bank height was not used to calculate the associated metrics. To address MDEQ's comments and allow comparisons of bank condition changes since 2011, the metrics were calculated in 2012 using bank heights extrapolated from the nearest bank survey location for

the 2011 and 2012 bank data. Photographs of the restored banks representing various BEHI categories are presented in Attachment 1. Table 3 summarizes the changes in bank classifications from 2011 to 2012. Relative reductions in bank erosion potential are highlighted in yellow, and relative increases in bank erosion potential are highlighted in purple on Table 3. As shown in Table 3, four bank locations showed decreased BEHI ratings and one bank area showed an increased BEHI rating. Changes in BEHI ratings for specific restored bank areas are discussed below.

In 2012, a portion of the north bank at Removal Area 13A (labeled Area D1 on Figure 12 and Table 3) exhibited increased root depth and vegetation, and a decreased bank angle that improved the BEHI rating to low compared to the 2011 rating of moderate (note: the 2011 moderate rating resulted from recalculation of the 2011 ratings based on bank heights). Similarly, a bank area upstream of the gas pipeline (labeled Area G1 on Figure 12 and Table 3) exhibited improved bank conditions that improved the BEHI rating from high (in 2011) to low (in 2012). BEHI ratings also improved at Removal Area 4A (labeled Area I2 West and Area I2 East on Figure 12 and Table 3), improving the BEHI ratings of these areas from moderate in 2011 to low in 2012, as a result of increased vegetation and decreased bank angles.

One bank area exhibited an increased BEHI rating in 2012 – a portion of the north bank upstream of the US 131 Bridge (Removal Area 4A) labeled Area I2 on Figure 12 and Table 3). This bank area exhibited decreased vegetation and increased bank angle that changed the rating from very low in 2011 to moderate in 2012.

The BEHI ratings for 2012 resulted in a decrease in the length of bank rated as very low erosion potential from 32% (4,067 feet) to 24% (3,070 feet); an increase in the length of bank rated as low erosion potential from 51% (6,450 feet) to 62% (7,835 feet); a decrease in the length of bank rated as moderate erosion potential from 16% (1,973 feet) to 10% (1,280 feet); and an increase in the length of bank rated as high erosion potential from 1% (160 feet) to 4% (460 feet) as compared to 2011 uncorrected values. (Note: Recalculation of the 2011 BEHI ratings using bank heights as described above resulted in an additional 360 feet of bank with a high BEHI rating in 2011, so the length of bank with high rating actually decreased in 2012.)

In general, the majority of the restored banks (86%) exhibit low or very low BEHI ratings. A smaller amount (10%) of restored bank exhibits characteristics that indicate a moderate potential for bank erosion, and 4% of restored banks have a high erosion potential, based on the BEHI rating. Vegetation density and root depths are continuing to increase, which is assisting in stabilizing the restored banks.

During the 2012 Trustee Site Walk, Area I2 (Removal Area 4A) and Area H1 (Removal Areas 9A and 10A) warranted additional evaluation due to their changed BEHI rankings. In addition, Area J1 (Removal Area 4B) warranted additional evaluation as it is the only area with a high BEHI rating.

4.3 Woody Vegetation Monitoring

The evaluation of the number of woody plants present in the restored habitats was conducted from May 2 to May 4, 2012. The results of the stem count are presented on Table 4 and detailed data are presented in Attachment 2. As shown in Table 4, a total of 3,732 trees and shrubs were planted in the project area by the completion of restoration activities in June 2009, and 10,115 planted and naturally recruited trees and shrubs were counted in 2012, resulting in 271% of the original planted stem count currently present. The overall 271% stem density exceeds the 85% performance standard that must be met by the third growing season.

Stem densities were further evaluated based on geographic location. The project area was separated into five geographic zones: north bank upstream of the US 131 Bridge, north bank upstream of the former Plainwell Dam, north bank downstream of the US 131 Bridge, south bank upstream and downstream of the US 131 Bridge, and south bank upstream of the former Plainwell Dam. As shown on Table 4, the 85% stem density performance standard was met in all five geographic areas.

Tree and shrub monitoring in Removal Areas 11A, 12A, and 13A performed in 2009 identified poor survival that did not meet performance standards. The poor survival was attributed to the inability of these species to compete with the taller and denser ragweed stand that developed where they were planted. Following discussions with USEPA and the Trustees in 2010, it was agreed that a fewer number of larger trees than originally planted (as opposed to planting a larger number of smaller trees) would be replanted in areas that were prepared by mowing the ragweed. As a result, 150 trees were planted in 2011 and 148 of those trees were found to be surviving during 2012 monitoring activities. Tabulated results of the monitoring are presented in Attachment 2.

4.4 Herbaceous Vegetation Monitoring

Herbaceous vegetation monitoring was performed from August 13 to 16, 2012. A total of 104 sample plots were randomly distributed throughout the restored areas to represent the herbaceous vegetative community. The average percent cover of all plots was 100%, as summarized in Table 5. The total percent ground cover of each plot and the percent cover of each identified species in the plot were recorded and are presented on a removal area-specific

basis in Attachment 3. These results indicate that the applied seed mixes were appropriate for the conditions in which they were applied. The 85% ground cover performance standard is currently being met in the final monitoring year. Photographs documenting restored vegetation in the removal areas are presented in Attachment 4.

5. Plainwell No. 2 Dam Area Bank Monitoring Results

Bank inspection and survey activities in the Plainwell No. 2 Dam Area were performed in April and May 2012. The following sections summarize the results of the surveyed transect comparisons, the BEHI ratings, the woody vegetation monitoring, and the herbaceous vegetation monitoring in the Plainwell No. 2 Dam Area. Supporting information is provided as follows:

- The cross-sections of the restored banks at the 14 permanent transect locations identified on Figure 13 are presented on Figures 14 through 17.
- The transect survey data are summarized in Table 6, the BEHI data are summarized in Table 7 and the erosion hazard ratings for the restored banks are presented on Figure 18.
- Photographs of the banks exhibiting various BEHI ratings are presented in Attachment 5.
- The results of the tree and shrub woody vegetation stem counts are summarized in Table 8 and the detailed data are presented in Attachment 6.
- Herbaceous vegetation data are summarized in Table 9 and the detailed vegetation data are presented in Attachment 7.
- Photographs of the vegetation status on restored banks are presented in Attachment 8.

5.1 Comparison of Bank Surveys

Fourteen permanent bank cross-section locations were benchmarked in 2010 to enable annual replication of the cross-sections to evaluate bank stability. The locations of the 14 transects are shown on Figure 13. Detailed bank survey data collected immediately following the physical restoration of the bank in 2010, and the survey conducted in spring 2011 and 2012 are compared on Figures 14 through 17. Year-to-year comparisons of observations made from the transect data are included in Table 6.

Survey transects were reviewed with the intention of identifying areas for additional inspection and discussion as part of the August 30, 2012 site walk (see Table 6). The lateral and vertical change in bank elevation from one monitoring event to the next is presented in the table. Although the change is quantified, the purpose of the table is to present a qualitative comparison of transect information. For this purpose, each value is rounded to the nearest half foot. Changes of less than 6 inches are within the range of error associated with survey data

collection and evaluation. Any observed change of less than half a foot is considered to be insignificant. The absolute value of material loss or deposition is not as important as the geometry of the bank profile from year to year. The profiles of the banks are classified as:

- Consistent with the previous year.
- Material loss or deposition was observed, but not to the extent that the bank may be at risk of immediate failure or the top-of-land use jeopardized.
- Material loss or deposition was observed, to the extent that extent that the bank may be at risk of immediate failure or the top-of-land use jeopardized.

In summary, 4 of the 14 transects (28%) showed a bank profile consistent with the bank profile observed in 2011; and 10 of the 14 transects (72%) showed evidence of either material deposition or loss at some location along the transect that altered the bank profile since 2011. One of these areas, Removal Area 3A, was identified as needing bank maintenance in 2012.

Of the 10 transects that showed evidence of material deposition or loss, material deposition above the water line was observed in 1 of the 10 transects (10%), material deposition below the water line was observed in 1 of the 10 transects (10%), material loss above the water line was observed in 1 of the 10 transects (10%), and material loss below the water line was observed in 8 of the 10 transects (80%).

5.2 Bank Erosion Hazard Index Ratings

Restored banks for the entire length of the project area were assigned BEHI ratings in 2012 based on bank characteristics observed in the field. Each length of bank that exhibited similar characteristics to a previously-characterized length of bank was assigned the same alphabetical label (A through H) in the field. Photographs of the restored banks representing the BEHI categories are presented in Attachment 5. Table 7 summarizes the changes in bank classifications from 2011 to 2012. Relative reductions in bank erosion potential are highlighted in yellow and increases in bank erosion potential are highlighted in purple on Table 7. As shown in Table 7, one bank location showed an overall decreased BEHI rating and one bank area showed an increased BEHI rating. Changes in BEHI overall ratings for specific restored bank areas are discussed below.

In 2012, Removal Area 3A on the north bank (labeled Area I1 on Figure 18 and Table 7) exhibited decreased root depth and vegetation, and an increased bank angle that raised the BEHI rating to moderate from the 2011 rating of low. The only other BEHI rating change from

2011 was associated with the northeast bank of Island 2 (labeled Area D on Figure 18 and Table 7), where increased vegetation improved the rating to low from the moderate rating in 2011.

As shown on Figure 18, 96% (9,210 feet) of the restored banks received a BEHI rating of low and 4% (430 feet) received a BEHI rating of moderate based on the 2012 monitoring effort. These results indicate that the majority of restored banks exhibit low erosion potential. Removal Area 3A was identified for additional inspection during the 2012 Trustee Site Walk due to the increased BEHI rating.

5.3 Woody Vegetation Monitoring

The evaluation of the number of woody plants present in the restored bank habitats of the Plainwell No. 2 Dam Area was conducted from April 30 to May 1, 2012. Tree and shrub monitoring in 2011 identified 70% of the originally planted stem density had survived, which did not meet the 85% stem density performance standard. Reasons for the low observed tree and shrub numbers include beaver and deer damage, mortality, and displacement by water.

As a result, supplemental trees and shrubs were planted in spring 2012 to restore the original number of plantings following remediation. A total of 1,022 trees and shrubs were planted. The distribution of plantings in the individual removal areas is summarized in Table 6. Replacement species were selected based on observed survival performance, with better surviving species preferentially selected over poor surviving species; however, the designed vegetative diversity was maintained in all replanted areas.

Replacement trees and shrubs planted during the 2012 monitoring activities were not included in the field counts, but the plantings were included in the summary tables to calculate 2012 stem densities. As shown in Table 8, a total of 3,104 plants were originally planted in the project area and 2,176 stems were counted in 2012, resulting in a 70% stem density. The inclusion of the 2012 plantings resulted in 103% of the original stem density currently existing in the restoration areas.

Stem densities were further evaluated based on geographical locations. The project area was segregated into eight geographic zones: Removal Area 1, Removal Areas 2 & 3A, Removal Area 3B, Removal Area 4A, Removal Area 5A, Removal Areas 4B & 5B, Removal Area 6, and Island 2. The 85% stem density performance standard was met in three of the individual geographic areas without using the 2012 counts, and met for seven of the eight areas when the 2012 plantings were included (Attachment 6).

5.3.1 Herbaceous Vegetation Monitoring

Herbaceous vegetation monitoring was performed between August 13 and 16, 2012. A total of 115 sample plots were randomly distributed throughout the restored areas to represent the herbaceous vegetative community. The average percent cover of all plots was 99.5%, as summarized in Table 9. The total percent ground cover of each plot and the percent cover of each identified species in the plot were recorded and are presented on a removal area-specific basis in Attachment 7. These results indicate that the applied seed mixes were appropriate for the conditions in which they were applied. Photographs documenting vegetation in the removal areas are presented in Attachment 8. The herbaceous vegetation will continue to be monitored for one more year to verify that the performance standard is met. Some weed control maintenance activities were implemented in fall 2011 and spring and summer 2012, as discussed in Section 6.5 of this Monitoring Report.

6. Maintenance Activities

6.1 Summary of 2012 Trustee Meeting

No bank repair activities were identified by the USEPA and the Trustees following the 2011 Trustee Site Walk and the 2011 Monitoring Report (ARCADIS 2011b).

On August 30, 2012, the fourth annual Trustee Site Walk was held to discuss the results of the 2012 bank monitoring activities for the former Plainwell Impoundment TCRA and Plainwell No. 2 Dam Area TCRA project areas. Meeting attendees included Ramon Mendoza of USEPA; Sharon Hanshue and Mark Mills of MDNR; Judy Alfano, Paul Bucholtz, and Nick Dawson of MDEQ; Lisa Williams of USFWS; Garry Griffith of Georgia-Pacific; Steve Garbaciak of Anchor QEA LLC; and Anthony Esposito, Eric Hritsuk, and EJ Suardini of ARCADIS. Both sites were inspected, with special emphasis being placed on the areas identified in the Spring 2012 Bank Monitoring Report (ARCADIS 2012a) as warranting additional inspection. Follow-up site visits were held on September 19, October 25, and December 3, 2012 and follow-up calls were held on September 17 and October 4, 2012 to discuss bank areas potentially requiring maintenance.

During the August 30, September 19, October 25, and December 3, 2012 site walks and September 17, 2012 and October 4, 2012 conference calls, seven areas were identified by the Trustees as requiring repair or additional attention/investigation.

Areas Requiring Repair

1. Former Plainwell Impoundment Western Channel

2. Former Plainwell Impoundment Removal Area 4A

3. Former Plainwell Impoundment Removal Area 6B

4. Plainwell No. 2 Dam Area Removal Area 3A

Areas Agreed to Require Further Attention/Investigation

1. Former Plainwell Impoundment Removal Area 10A

2. Former Plainwell Impoundment Removal Areas 7, 8, and 9B

3. Upstream of the Former Plainwell Impoundment Removal Area 2A

In addition, the USEPA and Trustees observed exposed geotextile in numerous areas within the former Plainwell Impoundment, and purple loosestrife was observed in the Plainwell No. 2 Dam Area. Addressing exposed geotextile is discussed in Section 6.3.4, and the invasive species control efforts are described in Section 6.5. These areas are discussed further in the remainder of this section.

6.2 Bank Repairs

Bank repairs were implemented in former Plainwell Impoundment Western Channel, Removal Areas 4A and 6B, and in Plainwell No. 2 Dam Area Removal Area 3A. A detailed description of these repairs is included in the November 15, 2012 Technical Memorandum (ARCADIS 2012b). USEPA approved these repairs in the November 20, 2012 letter (USEPA 2012c). Bank repair activities commenced during the week of December 10, 2012. An addendum to this Monitoring Report will be submitted to document completion of bank repair activities.

6.2.1 Former Plainwell Impoundment Western Channel

During the August 30, 2012 site walk, approximately 50 linear feet (ft) and 10 vertical ft of exposed geotextile fabric was observed on the south bank of the Western Channel downstream of the former Plainwell Dam. The exposed geotextile fabric will be covered with approximately 20 cubic yards of an angular rip rap placed from the top of bank. The plan view of the repair area and conceptual cross-section are shown on Figure 19. The bank slope is 3:1 and will not be altered by the repair.

6.2.2 Former Plainwell Impoundment Removal Area 4A

Approximately 500 ft of bank in Removal Area 4A have been monitored since 2009 and have exhibited signs of continuing erosion. The exposed bank between River Stations 55+00 and 60+00 will be covered with clean material to prevent contact between the river and the exposed residuals. The bank from River Station 52+50 to 60+00 will then be armored with stone to the prism-out 2-year storm water elevation (discharge of 3,845 cfs) to prevent erosion of the clean material. As recommended in MDEQ guidance (MDEQ 1998), a non-woven geotextile fabric will be installed on the imported fill slope prior to rock placement to protect against erosion behind the rock. The plan view of the repair area and conceptual cross-section are shown on Figure 20.

6.2.3 Former Plainwell Impoundment Removal Area 6B

Approximately 500 ft of bank in Removal Area 6B have been monitored since 2009 and has exhibited signs of continuing erosion. Rock armoring will be installed in Removal Area 6B from the toe of slope to the top of bank, which will provide hard armor to about the prism-out 2-year storm water elevation (discharge of 3,845 cfs) and address the erosion. As recommended in MDEQ guidance (MDEQ 1998), a non-woven geotextile fabric will be installed prior to rock placement to protect against erosion behind the rock. Live willow stakes will be installed in 2013 above the prism-out 2-year storm water elevation to support bank stability as woody roots develop and to increase the habitat quality of the floodplain by providing woody habitat. The plan view of the repair area and conceptual cross-section are shown on Figure 21.

6.2.4 Plainwell No. 2 Dam Area Removal Area 3A

As observed during the August 30, 2012 site walk, approximately 150 ft of bank in Removal Area 3A in the Plainwell No. 2 Dam Area is showing signs of losing bank material and an increasing bank angle, which is jeopardizing the stability of the bank.

The rock toe protection installed upstream of this bank repair location will be extended approximately 150 ft downstream to form a smooth, consistent toe of slope on the outside of the meander. Toe protection will extend from the toe of the restored bank to the median flow (950 cfs) elevation, as modeled in the Plainwell No. 2 Dam Area Design Report. In addition, a coir log will be installed at the interface of the top of the toe protection at the median water elevation. As recommended in MDEQ guidance (MDEQ 1998), a non-woven geotextile fabric will be installed prior to rock placement to protect against erosion behind the rock. The plan view of the repair area and conceptual cross-section are shown on Figure 22.

6.3 Areas Identified for Further Investigation

6.3.1 Former Plainwell Impoundment Removal Area 10A

Removal Area 10A was excavated in April 2008. As documented in Section 2.3.4 of the Former Plainwell Impoundment Final Construction Completion Report (ARCADIS 2010a), submerged material at the downstream end of Removal Area 10A and upstream end of Removal Area 11A could not be excavated due to the presence of two natural gas utility pipelines crossing the river. Material above the water line was excavated to the extent practical.

At the August 30, 2012 site walk, the Trustees observed a gray, clayey material that could indicate the presence of residual polychlorinated biphenyl (PCB) material. As described in a

December 7, 2012 letter (ARCADIS 2012c), this material was sampled to evaluate the presence of PCBs. Under the supervision of USEPA, five cores were advanced on December 17, 2012 (Figure 23). The fine-grain material from each location was homogenized and a single composite sample (RA10A_121712) was submitted to KAR Laboratories in Kalamazoo, Michigan for PCB analysis. On December 18, 2012, the cores were collected from the same five locations. The fine-grain material from each core was homogenized and one sample from each core (RA10A_121812-01, RA10A_121812-02, RA10A_121812-03, RA10A_121812-04, and RA10A_121812-05) was submitted to KAR Laboratories for PCB analysis. PCBs were not detected in any of the six samples submitted for laboratory analysis. Analytical data are included in Attachment 9. Based on these results no bank maintenance activities are warranted in this area.

6.3.2 Former Plainwell Impoundment Removal Areas 7, 8, and 9B

In discussion of potential bank repair activities, the Trustees recommended that armor stone be placed from the top of the existing coir log to the prism-out 2-year storm water elevation in Removal Areas 7, 8, and 9B (Figure 24) to minimize the potential for erosion to occur in these areas. The 2-year storm water elevation occurs at a discharge of 3,845 cfs. As described in the Background Section below, armor stone and coir log were previously installed in Removal Areas 7, 8, and 9B to address erosion that occurred during the 25-year storm event of September 2008, before TCRA activities were completed. The purpose of this further assessment is to evaluate whether additional armor stone needs to be placed in these areas. Removal Areas 7, 8, and 9B will be evaluated as a single area.

6.3.2.1 Background

Removal Areas 7 and 8 were excavated in the fall of 2007 as a part of the Former Plainwell Impoundment TCRA. Restoration was not completed at that time due to high water level and poor weather for vegetation establishment. Removal Area 9B was excavated in the spring of 2008. Restoration activities, which included seeding and planting of woody vegetation, were performed between June 2008 and June 2009.

6.3.2.1.1 Removal Area 7

Excavation activities in Removal Area 7 were completed in December 2007. During post-removal observations, it appeared that the removal of the mid-channel islands in this part of the river combined with the high flows that were experienced in February 2008 as a result of snow melt, led to higher-than-anticipated stress being placed on the bank. In consultation with the Trustees and following several inspections, a bank repair was implemented in June 2008 at Removal Area 7. The repair consisted of armoring the bank with river rock and installing a coir

log at the water elevation at the time of construction to protect the bank and allow establishment of vegetation. This repair is documented in the Former Plainwell Impoundment TCRA Final Construction Completion Report (ARCADIS 2010a).

6.3.2.1.2 Removal Areas 8 and 9B

Vegetation in Removal Areas 8 and 9B did not have sufficient time to establish itself prior to the September 2008 storm event. During a bank inspection in 2009 with USEPA and the Trustees, a section of bank in Removal Areas 8 and 9B was observed to have eroded during the high flow events that occurred in September 2008 and the winter of 2009. As a result, a portion of the 30-foot buffer between the river and the bank eroded.

In 2009, a bank repair was implemented at this location consisting of the placement of river run rock between the prism-out median flow and the river bed at an approximate 2:1 (horizontal: vertical) slope. In addition to the rock toe protection, the remaining portions of the shelf behind (landward) the rock were provided with additional erosion protection by the installation of a coir log. Seeding and erosion control fabric were installed landward of the coir log to promote vegetative growth to further stabilize the bank. The design of that repair and details of erosive forces in that area are described in detail in the September 15, 2009 letter to the Trustees titled Plainwell Bank Maintenance/Repair and Approach for Erosion in Removal Areas 8 and 9B (ARCADIS 2009b). The completion of the repair is described in the 2009 Former Plainwell Impoundment Bank Conditions Monitoring Report (ARCADIS 2009c).

During 2010 bank monitoring activities, an approximately 35 foot-long stretch of bank in Removal Area 9B was observed to be showing signs of localized erosion. The erosion observed was concluded to be caused not by river flow, but by stormwater runoff from Staging Area 3S. In order to repair the impacted area, the existing bank soil was graded to form a smooth slope throughout the area and river run rock was placed between the coir log and top-of-bank. The completion of the repair is described in the 2010 Former Plainwell Impoundment Bank Conditions Monitoring Report (ARCADIS 2011a).

6.3.2.2 Evaluation of Removal Areas 7, 8, and 9B

In an October 4, 2012 conference call, the Trustees recommended placing rock to the prism-out 2-year storm elevation in Removal Areas 7, 8, and 9B. This work was recommended to minimize the potential for future erosion of the clean buffer, which was reduced in width by the September 2008 severe storm event. Although the topography varies in Removal Areas 7, 8, and 9B, there is generally a 20- to 30-foot-wide flat shelf landward of the existing coir log, which transitions to an upward slope to the pre-TCRA floodplain elevation. The prism-out 2-year storm elevation is located on the slope between the flat shelf and pre-TCRA floodplain.

ARCADIS, on behalf of Georgia-Pacific, has reviewed the available data for this area and concluded that placement of additional rock is not warranted in these areas. The existing rock, coir log, and vegetation provide sufficient protection for the bank. The following data were reviewed, and will be described below, to support this conclusion:

- Survey Data
- Visual Observation/Photographs
- BEHI Evaluation
- Hydraulic Modeling
- Bank Composition

6.3.2.2.1 Survey Data

Bank profiles are surveyed annually at established transect locations to compare current bank geometry to immediate post-construction conditions and surveys from previous years. Transects T-6S, T-7S, and T-8S are located in Removal Areas 7, 8, and 9B, respectively (Figure 3). The bank profiles for Transects T-6S, T-7S, and T-8S are included on Figures 6 through 8 of this report.

As shown on the bank profiles, the post-construction (2007/2008) bank geometry changed in 2009 as a result of the 2008 storm event. However, since bank repairs were implemented in 2009, minimal change to bank geometry has been observed (see Table 2).

As described in Section 1.2.3, multiple flows exceeding the 2-year flow event have occurred since completion of the TCRA and subsequent bank repairs in the former Plainwell Impoundment. No significant erosion has been observed, and no additional bank repairs have been necessary since the completion of the work in 2009 and 2010.

6.3.2.2.2 Visual Observations/Photographs

Restored bank conditions are monitored annually for signs of erosion and sloughing. In addition, vegetation establishment is monitored annually by performing a woody vegetation count and herbaceous vegetation monitoring.

During bank inspection, restored banks were visually inspected for signs of erosion that could jeopardize the integrity of the banks or their functionality in the river system. The status of restored banks was evaluated by visual observation and comparison to design drawings,

considering location in the river, physical dimensions, and consistency with adjacent, undisturbed banks.

Vegetation establishment and development contributes to bank stability by providing: 1) ground cover that reduces the potential for erosion by sheetflow, and 2) physical support for banks from woody root systems. Areas of restored vegetation were characterized, and the percent cover and stem densities compared against the performance standards described in Section 2.2 to evaluate the development of the desired plant communities.

During bank inspections performed in April and August 2012, no obvious signs of erosion were observed and the number of woody plants present in the area is exceeding the number of trees and shrubs planted as a result of natural recruitment (Table 4). Woody vegetation extends the root depth of bank vegetation, which aids in soil retention during storm events. Herbaceous vegetation is also well established in Removal Areas 7, 8 and 9B (see Table 5) – as documented in the photographs included in Attachment 10, these banks are well vegetated bank with a diverse herbaceous plant community that also contributes to bank stability by reducing water flow velocity over the bank.

6.3.2.2.3 BEHI Evaluation

As described in Section 3.3, the monitoring program utilizes components of the BEHI methodology developed by Rosgen (1996) to evaluate bank conditions. The BEHI integrates information regarding the relationship of the top-of-bank height to the bankfull water elevation, the vertical extent of root penetration in the bank, the root density, the bank angle, and the percentage of bank surface protected by vegetation or armor to identify a qualitative BEHI.

The comparison of the BEHI ratings provides a general indication of changes in bank conditions and may assist in identifying areas where bank conditions may warrant consideration for maintenance. BEHI ratings of “low” and “very low” can be considered to have a low potential for erosion; BEHI ratings of “high” or “extreme” have a higher potential for erosion; and a “moderate” BEHI rating falls between these conditions.

The BEHI for Removal Areas 7, 8, and 9B is shown on Figure 12 and Table 3 (Areas O2 and J2). This section of the river was rated as having a “moderate” BEHI.

6.3.2.2.4 Hydraulic Modeling

A hydraulic analysis of anticipated post-construction conditions was conducted as part of the TCRA design to assess the extent and impact of potential scour and erosion. The hydraulic analysis is included in Attachment E of the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007) and summarized in the October 3, 2012 letter titled Review of Hydraulic

Modeling Near the Former Plainwell Dam in Plainwell, Michigan to Evaluate Effects of Remaining Stored Sediment on Bank Stresses (ARCADIS 2012d). That letter focuses on the area downstream of the Western Channel, but the description of the hydraulic analysis is relevant to Removal Areas 7, 8, and 9B. The summary of the hydraulic analysis presented in the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007) will not be repeated here.

Results of four hydrodynamic simulation scenarios are available for the following conditions:

1. Existing Conditions (pre-TCRA)

2. During TCRA Construction Activities

3. Immediately Post-TCRA (before erosion of the mid-channel prism)

4. Long-Term Post-TCRA (after erosion of the mid-channel prism)

Scenario 3, the immediate post-TCRA condition, represents the extreme of near-bank stresses resulting from the presence of the mid-channel prism. As the prism has eroded over time, potential effects on the banks due to the presence of the prism have been subsiding. Therefore, that scenario is of most relevance to evaluating worst-case conditions and was evaluated in the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007). As stated in a submission titled Former Plainwell Impoundment TCRA Mid-Channel Prism Volume Remaining and Completion of Bathymetry Survey Activities (ARCADIS 2010b), prism loss in this area is generally complete. Therefore, Scenario 4 more closely represents the current flow conditions. However, in order to conservatively assess near-bank stresses present in Removal Areas 7, 8, and 9B, Scenario 3 is evaluated here.

Post-construction water velocities were modeled for the 100-year flood event with (Figure 25) and without (Figure 26) the mid-channel prism to illustrate the distribution of water velocities within the project reach. Removal Areas 7, 8 and 9B are located along the inside bend of a large gradual meander that was anticipated to be a depositional area following removal and revegetation activities and not subject to erosional forces requiring rock-based armoring. As shown in Figures 25 and 26, the velocity was calculated to be 2 to 4 feet per second (ft/s) for the 100-year storm event. Bank areas exposed to predicted water velocities greater than 5 ft/s during the 100-year storm event were further evaluated in the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007) to assess whether additional bank protection was warranted. Since predicted water velocities did not exceed 5 ft/s in Removal Areas 7, 8, and 9B, rock was not initially placed in these areas.

Figures 27 and 28 present the velocity and shear stress predicted by the RMA2 model for post-construction conditions (prism-in) during a 2-year storm event, as presented in the Former Plainwell Impoundment TCRA Design Report (ARCADIS BBL 2007). The near-bank shear stress and velocity were calculated to be 100 to 150 dynes per square centimeter (dynes/cm^2) and 2 to 4 ft/s, respectively for the 2-year storm event. Vegetated banks are capable of withstanding shear stresses of 1,500 dynes/cm^2 (American Excelsior 2009) and velocities of up to 7 ft/s. Therefore, now that the banks are fully vegetated, the area between the coir log and the water elevation during a 2-year storm event is expected to be stable under high-flow conditions.

Based on the modeled shear stress and water velocity, the banks should have been stable to these maximum tolerances if vegetation had become established before the fall 2008 flood event. However, vegetation did not become established prior to that event. The banks are now protected with river run rock, coir log, and well-established herbaceous and woody vegetation.

According to Attachment J of the Former Plainwell Impoundment Design Report (ARCADIS BBL 2007), the river run rock is modeled to protect against velocities between 6 and 7.5 f/s, which are significantly higher than the velocities expected during the 2-year or 100-year storm event.

6.3.2.2.5 Bank Composition

Bank erosion has typically occurred in areas where sandy soil is exposed to river flow, such as Removal Area 6B. Removal of the fine-grained sediments exposed the native sandy material in some portions of the Site. Sandy bank soil was exposed below the median flow elevation in Removal Areas 7, 8, and 9B, and it was this material that was eroded as a result of the September 2008 storm. The previous bank maintenance completed in Removal Areas 7, 8, and 9B was designed to isolate the exposed sandy soil from the river by the placement of geotextile, rock, and coir log. Clayey soils landward of the rock and coir log at the water's edge are more resistant to erosion, particularly when vegetated, and vegetation is currently well established on those soils.

6.3.2.3 Conclusion of Removal Areas 7, 8, and 9B Evaluation

Based on the survey information, visual observations, BEHI rating, hydraulic modeling, and bank composition for Removal Areas 7, 8, and 9B, placement of additional rock in these areas is not warranted. Based on the modeling assessment, had vegetation established on the banks prior to the 2008 storm event, erosion of a portion of the 30-foot buffer likely would not have occurred. However, the banks were not vegetated prior to this event and the erosion did occur. In response, Georgia-Pacific and ARCADIS added rock and coir log to the water level at the

time of construction (approximately the prism-out median water elevation) to provide protection. The vegetation has since established itself in this area landward of the coir log. Repeat survey and monitoring show that the bank geometry has remained unchanged through four 2-year storm events since installation of the rock and coir log. Based on all of this information, it can be concluded that the banks are sufficiently stabilized with the existing rock, coir log, and established vegetation to prevent any substantial erosion.

In order to address Trustee concerns for the protection of the buffer area, live willow stakes will be installed in spring 2013 in the buffer zone and landward of the existing rock bank armoring to further increase the density and depth of roots and increase the soil holding capability of the bank. Live staking and incorporation of root wads in the rock armor interstices is a common practice used to enhance habitat quality and increase bank stability (Fischenich 2003).

6.3.3 Upstream of the Former Plainwell Impoundment Removal Area 2A

During the December 3, 2012 site visit (USEPA 2012b), erosion was observed in the area between Removal Area 1 and Removal Area 2A that was not included as a part of the TCRA. USEPA recommended repair to this area to prevent future erosion. However, in an email to USEPA, dated December 11, 2012 (Griffith 2012), that documented a December 10, 2012 phone conversation between USEPA and Georgia-Pacific, USEPA agreed that the observed erosion in this area is likely the result of biological activity and bank repairs are not warranted.

6.3.4 Former Plainwell Impoundment Exposed Geotextile

Areas of exposed geotextile were identified in the November 20 (USEPA 2012c) and December 7 (USEPA 2012b) USEPA correspondences. Rock will be hand placed to the extent practical in these areas during bank repair work in the former Plainwell Impoundment.

6.4 Invasive Species Control

Implementation of an exotic/invasive species control program is one part of a successful revegetation program. Species to be monitored for the project areas include exotic/invasive species and other aggressive species with a tendency to develop into mono-cultures, such as broad-leaved cattail (*Typha latifolia*), common reed (*Phragmites australis*), multiflora rose (*Rosa multiflora*), purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), autumn olive (*Elaeagnus umbellata*), garlic mustard (*Alliaria petiolata*), and yellow iris (*Iris pseudacorus*).

Control of exotic/invasive species may be accomplished through the physical removal of specimens, or through broadcast or spot spraying of glyophosphate herbicide, such as Rodeo®, by a licensed applicator. Initial exotic/invasive species control was performed concurrently with restoration activities. Additional weed control activities that may be required will be discussed with USEPA and the Trustees as part of the annual Trustee Site Walk.

During the 2011 monitoring inspections, several patches of *Phragmites* were observed in restored habitat areas of the former Plainwell Impoundment, and dense stands of reed canary grass were considered to be shading out small planted trees and shrubs in the Plainwell No. 2 Dam Area. Therefore, Georgia-Pacific contracted Cardno JFNew of Grand Haven, Michigan to control these weeds, and herbicide was applied in summer 2011, fall 2011, and spring 2012. The effectiveness of the treatment was evaluated during the fall 2012 vegetation monitoring effort. The treatment activities were observed to have eliminated or reduced the density of weeds in the restored areas to no longer compete with desired species or dominate the restored plant communities.

Several dense patches of purple loosestrife were observed in restored riparian habitats of the Plainwell No. 2 Dam Area during the 2012 Site Walk. Herbicide applications in 2011 did not significantly reduce the purple loosestrife presence in this reach. Therefore, a biological control is planned to be implemented in 2013 to control the density and potential spread of the loosestrife. Beetle-infested purple loosestrife plants will be planted in areas of with dense purple loosestrife stands, and the beetles will spread onto adjacent plants. The beetles function primarily to defoliate the loosestrife plants and the increased stress on the plants reduces their ability to produce seeds. The effectiveness of the biological control will be qualitatively evaluated during 2013 vegetation monitoring activities.

7. Future Monitoring and Reporting Activities

7.1 Former Plainwell Impoundment

On March 30, 2013, the monitoring requirements as defined in the Former Plainwell Impoundment AOC (USEPA 2007) terminate. Georgia-Pacific will perform the following future monitoring and reporting activities to complete the monitoring requirements defined in the AOC (USEPA 2007):

1. Submit an addendum to this report documenting completed bank repair activities.

2. Meet with the MDNR to develop a plan to transfer the monitoring and maintenance program for the Former Plainwell Impoundment TCRA site to the MDNR.

3. Conduct a collaborative inspection of the banks and restored habitats with USEPA and the Trustees no more than 60 days prior to the 3-year anniversary of the Notice of Completion of Work for the Former Plainwell Impoundment (March 30, 2013).

7.2 Plainwell No. 2 Dam Area

Georgia-Pacific will continue monitoring efforts in the Plainwell No. 2 Dam Area in 2013. Based on discussions with USEPA and the Trustees, bank monitoring activities in 2013 in this area will consist of the following tasks.

1. Implementation of bank repair activities.

2. An addendum to this report summarizing bank repair activities.

3. Submit the draft annual monitoring report to USEPA and the Trustees summarizing the spring observations and evaluations (July).

4. Conduct a collaborative inspection of the banks and restored habitats with USEPA and the Trustees in summer (August) and identify any areas requiring corrective action.

5. If a corrective action is required, submit a design for any potential corrective action to USEPA and the Trustees for review and comment.

6. After USEPA and Trustee review, implement the corrective action as appropriate.

7. Perform the summer quantitative vegetation evaluation to evaluate percent cover and diversity metrics.

8. Submit the annual monitoring report to USEPA and the Trustees by the end of the year.

9. Conduct a collaborative inspection of the banks and restored habitats with USEPA and the Trustees no more than 60 days prior to the 3-year anniversary of the Notice of Completion of Work for the Plainwell No. 2 Dam Area (March 1, 2014).

This process will allow USEPA and the Trustees to review information about the restored banks and habitats early enough in the year so that any issues identified during the collaborative project area inspection can be designed and implemented in the same year as the monitoring is being performed.

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